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Poster paper

Mechanical systems for a synchrotron X-ray-enhanced scanning tunnelling microscope

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Synchrotron X-ray-enhanced scanning tunnelling microscopy (SXSTM) is a novel technique by which materials can be studied with elemental-sensitive and nanometre-spatial resolution. This poster covers the mechanical engineering design for the prototype SXSTM instrument. System performance and sample handling requirements along with the desire to use existing components constrained the design. The SXSTM needs to be mechanically and acoustically isolated from the environment. In addition, all sample preparations are done *in situ*, and thus, the sample and SXSTM tips need to be prepared and moved inside the vacuum chamber with a wobble stick. The final design incorporates an Advanced Photon Source-designed vacuum chamber, existing components and commercial parts to provide the user with a robust prototype system to demonstrate the impact of this new technique.

1. Introduction

A scanning tunnelling microscope (STM) can be used to image surfaces with atomic resolution. Synchrotron X-ray enhanced scanning tunnelling microscopy (SXSTM) supplements the atomic spatial resolution of the STM with the elemental-resolving capability of X-ray techniques. That is, the scanned probe provides the fine spatial resolution, while the selectable wavelength of X-rays provides for the discrimination of chemical, electrical and magnetic characteristics. Successful development of the SXSTM technique will provide synchrotron users with an important new technique for the quantification of surfaces and nanostructures (Rose *et al.* 2008).

Scientists and engineers at the Advanced Photon Source (APS) at Argonne National Laboratory have collaborated on the integration of an Omicron STM head into a prototype user SXSTM instrument (Omicron NanoTechnology, 2010). In the STM technique, a sharp tip is brought in close proximity to a conductive sample. A bias voltage between the tip and sample allows electrons to tunnel across the gap between them. The topography is determined by rastering the tip across the sample, keeping the tunnelling current constant. In the SXSTM technique, the sample is illuminated with synchrotron X-rays and the conventional tunnelling

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current will be modulated by X-ray-excited electrons (Rose *et al.* 2008). In both cases, the tip-to-sample distance is in the nanometre range. A few engineering challenges need to be overcome to adapt STM to the synchrotron beamline.

2. System design

The engineering challenges of integrating the SXSTM into a beamline at the APS were translated into five design constraints: (*a*) STM manipulation for X-ray illumination (*b*) sufficient mechanical isolation, (*c*) sufficient acoustic isolation, (*d*) an ultra-high vacuum (UHV) environment (better than 1E-9 Torr) and (*e*) *in situ* sample handling and preparation. Fortunately, some of these constraints were synergistic and others were not coupled. The final design, shown in figure 1, was a UHV vessel containing all of the sample manipulation and preparation hardware along with vibration isolation.

Constraints 1, 3 and 4 are interrelated and necessitated the installation of the SXSTM head in a vacuum vessel. This chamber served to couple the instrument to the beamline for low-energy X-ray experiments, decouple the SXSTM head from the acoustic environment and ensure a clean environment for sample preparation and measurement. While these constraints dictated the need for the vacuum chamber, the other constraints determined the shape and configuration of the vessel.

The most important constraint was the need for mechanical isolation of the SXSTM head from the APS environment. The APS has a relatively quiet ground vibration environment, though the ground vibration can be amplified by the resonances of the instrument support structure. Measurements on a previous prototype SXSTM revealed that the system vibrations exceeded the STM manufacturer's recommendation in some areas of the frequency spectrum and were relatively close in others (see figure 2).

A passive vibration isolation stage from Omicron was selected to address the vibration problem. The mount, shown in figure 1(*b*), has soft springs that provide

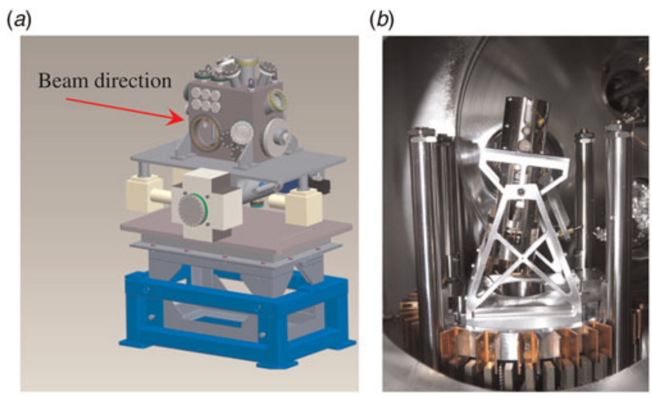

FIGURE 1. (*a*) SXSTM instrument showing X-ray beam direction, vacuum vessel and support table. (*b*) Close-up of the SXSTM head installed in a vacuum vessel showing the vibration isolation system. The copper plates are located between permanent magnets and provide eddy-current damping in the vertical direction. The angle of the SXSTM head with respect to the incident beam can be adjusted.

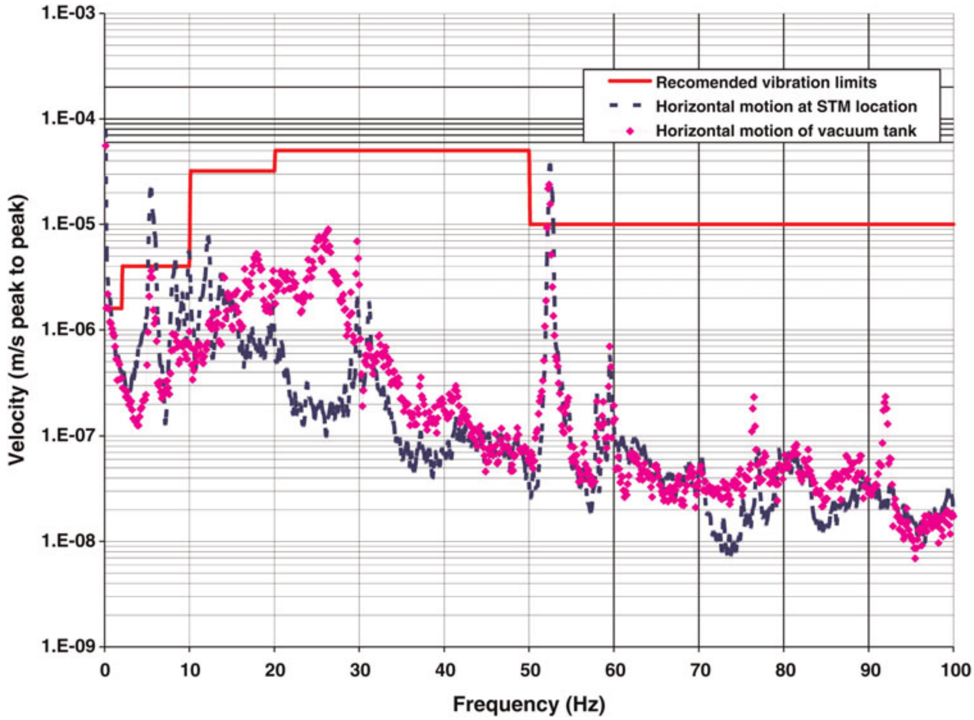

FIGURE 2. Comparison of Omicron-recommended vibration envelope, the vacuum tank vibration and STM support vibration.

good attenuation above the mounting frequency of a few hertz and eddy-current damping that provides sufficient attenuation at resonance.

The final constraint was the sample preparation and manipulation. All sample transfers from the cleaning/deposition manipulator to the SXSTM head were performed with a wobble stick. The wobble stick range of motion determined the relative location of the SXSTM, sample manipulator and wobble stick, and thus the configuration of the vacuum vessel.

3. Discussion

As of June 2010, the instrument had seen two periods of beam time and worked as expected. Currently, modifications are being made for improved sample and tip handling and storage.

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